SSC-SDC-42

SSC-SDC
SOLENOIDAL DETECTOR NOTES

A DETECTOR DESIGN

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Abstract: We have begun to study the dynamics of assembling a large SSC detector in a underground hall using a particular model for a solenoidal detector to improve our understanding of detector tolerances and construction specfications. We have established floor space needs; schedule, power, HVAC and utility requirements.

As we will show below the design and construction time for an SSC detector is about seven to eight years. This includes one year of hall design work, 3 years to construct the hall and 3 to 4 years to assemble the detector in the completed hall. The hall design must take into account the specifics needs of the detector. Given a target date for SSC operation in late 1998, these times imply that the final design of the hall must begin with the submission of the proposal, now scheduled for late 1991. Any major detector sub-systems which require special facilities in the hall must be identified and their needs included in the specification for the hall design. Hence, the hall design must be sufficiently flexible to accomodate facilities for any detector subsystem for which there is more than one option. We describe here an effort to try and develop the tools and information needed to effectively design an interaction hall and surface facilities for a large SSC Detector.

The work described here was done in collaboration with the engineering firm 'RTK' [1], of Oakland, California. This firm is under contract to the SSCL to perform geotechnical and cost studies of the underground interaction regions. The goals of the project were to:

1) Study the construction procedure for a detector to obtain an appreciation of the degree of difficulty of fabrication, assembly, disassembly and maintenance in an underground hall;
2) Define the hall configuration and the space requirements for the equipment, construction equipment access, operating access, personnel access, laydown areas, assembly procedure and assembly device storage;
3) Simulate the construction sequence to improve scheduling of the construction operations;
4) Specify needed utilities, such as electrical power, HVAC, and cooling water;
5) Estimate required above ground facilities and space requirements.
6) Compare above ground assembly with below ground assembly of major subsystems from a cost and schedule point of view.

We chose a simple detector design, but with sufficient complexity so that realistic studies could be made. The intent was not only to study 'a' particular detector, but to begin to develop tools and collect information that could be applied to a broad range of detectors based on solenoidal magnets. In order to concentrate our efforts on hall design, rather than detector design, we chose a baseline detector configuration which minimized the mechanical interaction between sub- systems. Figures 1 is a cross sectional view of the detector; the plan view of the detector is shown in Figure 2. The solenoid coil design was based on 'air-core' or short solenoid [2]. This magnet does not use iron near the ends of the coil and hence the external forces on the coil cryostat and the calorimeter are dominated by gravity. Any electromagnetic forces between the calorimeter and coil have been ignored. The tracking system selected was a silicon inner tracker with an outer tracker. The outer tracker is further divided into a central and intermediate regions. The calorimeter was loosely based on the Warm Liquid design by EG&G [3] , but the results described here would apply equally to any self-supporting calorimeter built from 'modules' of order 20 to 50 Tons. The calorimeter modules are assembled into 5 cylindrical bays: 3 cental bays and two endcap bay. Each bay is about 3 meters long along the beam line and weighs of order 1200T.

The calorimeter is surrounded by magnetized iron muon toroids, 1.2 meters thick in the barrel region ($|\eta| < 1.5$) and about 4 meters thick in the intermediate region between $2.5 > |\eta| > 1.5$. There are four planes of muon chambers in the barrel region, and six in the intermediate angle regions. A major concern for the configuration of the muon steel is access to the calorimeter, and we considered two alternatives: 1) the barrel muon steel fixed in the hall with sufficient space inside to allow personnel access between the muon steel and calorimeter for electronics repairs; 2) movable barrel muon toroids.

Before proceeding with the hall design, we first considered the geography in which the hall is situated. Table I lists a number of parameters for the hall location, and our design is appropriate for IR1 or IR2 of this table. At this point the beam line is about 52 m (175 ft) underground. Note that because the accelerator is not parallel to the local direction of gravity, the beam-line passes through the interaction point at an angle of 0.09° with respect to the vertical. This corresponds to a change in height of 12.5 cm over 80 meters (the approximate size of an underground hall).

Based on previous work for the LSD detector [4], we looked at the cost of changing the width and length of the hall. The results are shown in Figure 3. For a hall of nominal width 28 meters and length 80 meters the cost of the hall is about \$27M. From the slope of the curves, one can derive that for adding a small area, it is marginally cheaper to make the hall wider (\$4.2K/m^2) than it is to make it longer (\$5.0 K/m^2). However, the usefulness of the area is probably maximized if the hall is made longer, and we have generally made the hall as narrow as possible perpendicular to the beam line to accommodate the detector (plus access space) and added length to the hall if additional floor space is necessary.

One concern was the amount of floor movement as heavy pieces of the detector are moved about. We suggested a combined nominal tolerance of 2.5 mm of non-elastic or elastic floor motion for short duration ($\sim$ 1 Week) motions of heavy (1200T) objects. Over the period of a year settling of order 2-3 cm could be tolerated. To gain some insight into the 'scale' of the deformation of the floor, we considered a simple ANSYS model for the soil motion. Figure 4 shows the result for the soil motion at the bottom of the excavation when the overburden of the soil is removed. The total motion or heave of the soil at the floor of the hall is 18 cm (7 in). More importantly, the net heave of the soil between the middle of the hall and the corner is 6.5 cm (2.7 inches), assuming laboratory values for the Young's Modulus and Poissons ratio of the soil. Since these values are large compared to our tolerances, some care will have to be taken in the design of the floor of the hall to insure that our tolerances can be met. A large boring (approx 2.5 m diameter) near the site of the interaction regions is in progress at the SSCL to obtain better numbers to characterize the soil properties.

After some initial investigations, we quickly learned some general lessons about the hall and the detector that should be applicable to any of the solenoidal detector options:

1) Hall designs from the SSCL had the construction shaft (the major vertical access shaft for large objects) directly centered over the beam line. Once the accelerator is installed, the construction shaft is then rendered relatively useless since the floor under the shaft is occupied by accelerator components. We have located the shaft to one side of the hall.
2) The area of the construction shaft should be minimized: For safety reasons the area under the construction shaft is not useable except for temporary storage. Personnel and experimental equipment must be moved away from under the shaft to avoid falling objects.
3) Given that most of the assembly sequence and maintenance procedures require the motion of large detector components along the beam line, it seems prudent that the long dimension of the hall is parallel to the beam, not perpendicular.
4) In a similar vein, it seems clear that the detector does not want to be centered in the hall, either along the length or in the transverse dimension. Keeping the beam line to one side of the hall in the transverse dimension means that large objects can be moved from the construction shaft to the opposite end of the hall without disturbing the detector or making the hall too wide. Keeping the detector towards one end of the hall in the beam direction means that a relatively large, independent area can be created for the assembly of major subsystems, such as the calorimeter bays. If most of the muon steel is fixed in the hall, this is the most appropriate place for the assembly space. This space can be used later in the life of the experiment for maintenance or disassembly when older subsystems are replaced with new technology. The design of the accelerator provides for operation of the accelerator in a by-pass during major upgrades or repairs.
5) The amount of floor motion is still uncertain, and the muon system requires chamber placement accuracy of order 100 microns. It therefore seems prudent to keep most of the muon iron toroid fixed in place in order to minimize displacements of the floor. We considered an assembly scenario with moving steel, and discovered that at no time during the assembly sequence did we actually need to move the steel as long as we maintained an access space between the calorimeter and the muon steel. This access space is used for maintenance of calorimeter, tracking system and the muon system electronics inside the toroids. Hence, our current judgment would be to keep the steel of the barrel muon toroids to be fixed in place.

Figure 5 shows a 3-dimensional view of the empty Hall. The final location of the detector is evident in the lower half of the figure. OHSA regulations require emergency exit tunnels about every 90 ft. These emergency shafts are located at each end of the hall along the top edge of the picture. These vertical shafts are dug outside the excavation area for the hall proper. They are located 34 meters away from the hall and connect to the hall via lateral tunnels. Keeping these two shafts outside the main excavation allows access to the hall for installation of conventional electrical systems, HVAC, etc before the excavated soil is replaced. This allows access to the hall about one year earlier than if the shafts are within the area excavated for the Hall.

One of these two shafts ('personnel shaft') on the left side of the figure contains a stairwell, elevator, HVAC duct work and fire protection systems. The shaft at the far right side of the figure ('equipment shaft') also contains a stairwell, a shaft for lowering smaller pieces of apparatus (up to 35 T) and air handling ducts. Trigger and Data-acquisition cables are routed to the surface via a third small shaft centered on the detector. A forth shaft, also near the center line of the detector is used for carrying major utilities to and from the surface: liquid and gaseous Nitrogen and Helium, low conductivity water, industrial chilled water, speciality gases for detector sub-systems, as well as current leads for superconducting and conventional magnets. All of these shafts are located on the same side of the hall to keep the above ground areas well organized; minimize the underground area used for traffic lanes and avoid interference with the accelerator bypass. Cross sections of these four shafts are shown in figure 6.

The last and largest shaft is the construction shaft located in the bottom left of figure 5. It is through this shaft that large pieces of apparatus are lowered into the hall. Examples are the muon steel, superconducting coil, and mechanical supports for the calorimeter. Note that the construction shaft is not centered above the beam line, and with the detector located to one side of the hall, we have generated a wide lane along the side of the detector for transporting material from the construction shaft to the opposite end of the hall. This shaft is also used in conjunction with a duct system on the roof of the hall for smoke removal in case of a fire.

During the initial assembly of the detector the hall is partition into two volumes 1) a large volume centered on the final position of the detector where the muon steel is assembled and 2) a calorimeter assembly area. These two volumes have independent air systems to reduce contamination between the muon steel assembly area and the relatively clean area needed to assemble the calorimeter.

In the course of our work we have created a sequential set of drawings for the construction of the detector showing the activity in the hall at roughly 3 month intervals for the entire 42 month assembly process. Figures 7, 8, 9 and 10 are examples from this work showing the state of the hall at the 9th month, 18th month, 30th month and 42nd month of the construction schedule, respectively. The 3 dimensional model of the detector has been used to verify that sufficient room exists in the hall to perform all of the work needed, including space for two large assembly fixtures needed to construct the calorimeter, as well as fixtures for installation of the coil and tracking.

We also considered an assembly scenario where the calorimeter bays are assembled above ground and lowered as five 1200 ton units into the hall. The assumption here is that tasks are more efficiently performed above ground versus below ground and that in an above ground facility one could consider building two calorimeter bays at a single time. This could reduce the assembly time for the detector. One might also imagine that some cost savings could apply since the below ground hall could be made smaller. At present we do not favor this scenario for two reasons:

1) The cost of a large crane was estimated at $75,000 setup, $50,000 per month operating charges and $75,000 to disassemble. We would need such a crane for about a year. It was found to be cheaper (on the basis of figure 3) to add additional space to the hall.
2) In the event of a major repair or upgrade to of the detector, one would require sufficient below ground area for disassembly of the detector. This disassembly space is about the same needed for construction.

Further study of above ground assembly is in progress to test these impressions.

One of the issues for this project was to collect as best as possible information on the electrical power and facilities needed to operate the detector. We have developed a relatively detailed EXCEL spreadsheet to estimate the total power, HVAC, LHe, LN2 and other utilities used by the detector. Table II, taken from this spread sheet, summarizes the electrical power requirements for the detector. The total power required by this detector is estimated to be about 15MW. One important parameter is the fraction of the total power load dissipated inside the steel of the muon toroids, either from the electronics or the coils on the muon steel. If 1% of the power in the toroid coils is transferred to the air inside the toroids, 20KW of heat must be removed in air conditioning or a thermal shield. Assuming that most of the electronics is water cooled, the dominate heat load on the air-conditioning could be heat dissipated by the coils. It is difficult to remove large, diffuse heat loads inside this enclosed volume without high air velocities and the thermal management of the heat loads and cooling sources inside the muon steel will be an engineering challange.

Finally, in Figure 11 we show an abbreviated schedule for the assembly of the detector. As noted earlier, after occupancy of the hall, about 3 and 1/2 years is needed to assemble the detector. According to the schedule, the first 60 (of about 350) calorimeter modules are needed about 6 months after occupancy of the hall and the last calorimeter module is installed one year before beam is available.

To conclude, we have identified several interesting features concerning the assembly procedures of a large detector in an underground hall. Given the long assembly time for the detector and an estimated three year construction time for the hall itself, it is advisable that major technology choices be made as early as possible so that hall design can be finalized. Some aspects of the hall design still need study, even at this general level of work described here. The first of these are the definition of special safety requirements for the detector subsystems. Of particular concern are liquid calorimeters, either Liquid Argon, liquid scintillator or warm liquids, which have either ODH or flammable liquid safety issues. A second concern is any detector subsystem that might require a shielded room at roughly beam level that can be occupied when the SSC is in operation. We have not as yet identified a need for such a room in our particular design example, but the need for such a room might arise. As this work progresses we hope to attack these and related issues.

References

1. 'RTK', a joint venture: Kaiser Engineers, Inc, Tudor Engineering, and Keller & Gannon-Knight.
2. Y. Doi, et al, "Design Study of a Short Solenoid for the SDC Detector", Proceedings , "International Workshop on Solenoidal Detectors for the SSC", KEK, April, 1990.
3. T. Ballinger, et. al, "Engineering Design Study of a Warm Liquid Calorimeter Concept for a Detector at the SSC", EG&G Energy Measurements, Report AVO-395, Sept, 1989.
4. See, for example, G. Hansen, et. al., "Report of the Large Solenoid Detector Group", in R. Donaldson, G. Gilchriese, editors "Proceedings of the International Workshop on Experiments,Detectors and Experimental Areas for the Supercollider", Berkeley, Ca., 1987, page 340.

Table Captions

1) Detailed geotechnical Parameters of the SSCL Halls. This detector was designed assuming the parameters of IR-1 or IR-2. "Depth to Material interface" is the depth to the boundary between the "Austin Chalk (AC)" and "Eagle Ford Shale (EFS)" strata.

2) Power requirements for the detector. The detector electronics are assumed to be powered via 400 Hz low voltage power supplies. Some conventional 60Hz power is used for the detector. An example is any high voltage power supply. In the computation of the total 'line power' we have taken the total power from the 400Hz, 60 Hz detector and 60 Hz (other) columns and included effects due to power supply efficiency, spare capacity, diversity and power factors.

Figure Captions

1) Cross section of the "RTK Baseline" Detector.

2) Plan view of the "RTK Baseline" detector.

3) Cost of the hall as a function of its length and width. Included in the estimate are excavation, concrete, conventional electrical power, HVAC, cranes, backfill, etc. The hall priced here had three shafts: a) a personnel shaft ($2.3M incl elevator and services), b) a construction shaft for large objects ($0.50 M) and c) an equipment shaft ($0.58M) for smaller pieces of equipment and personnel access.

4) ANSYS simulation for the net vertical heave of the soil at the floor of the hall when the overburden is removed. The element size is 5 Meters in both directions and the vertical displacement has been exaggerated for clarity. Several cases were run assuming different soil properties. Values for the soil properties as measured in the laboratory on the basis of a small test boring at the SSCL site are indicated.

5) Three dimensional view of the detector hall showing the location of the access shafts. The final detector location is centered above the support structures shown in the left-half of the hall.

6) Cross section of four shafts: a) personnel shaft, b) equipment shaft, c) DAQ/Trigger cable shaft, d) Utility shaft.

7) State of the hall at 9 months into construction.

8) State of the hall at 18 months into construction.

9) State of the hall at 30 months into construction.

10) State of the hall at 42 months into construction.

11) Simplified schedule for the detector assembly.

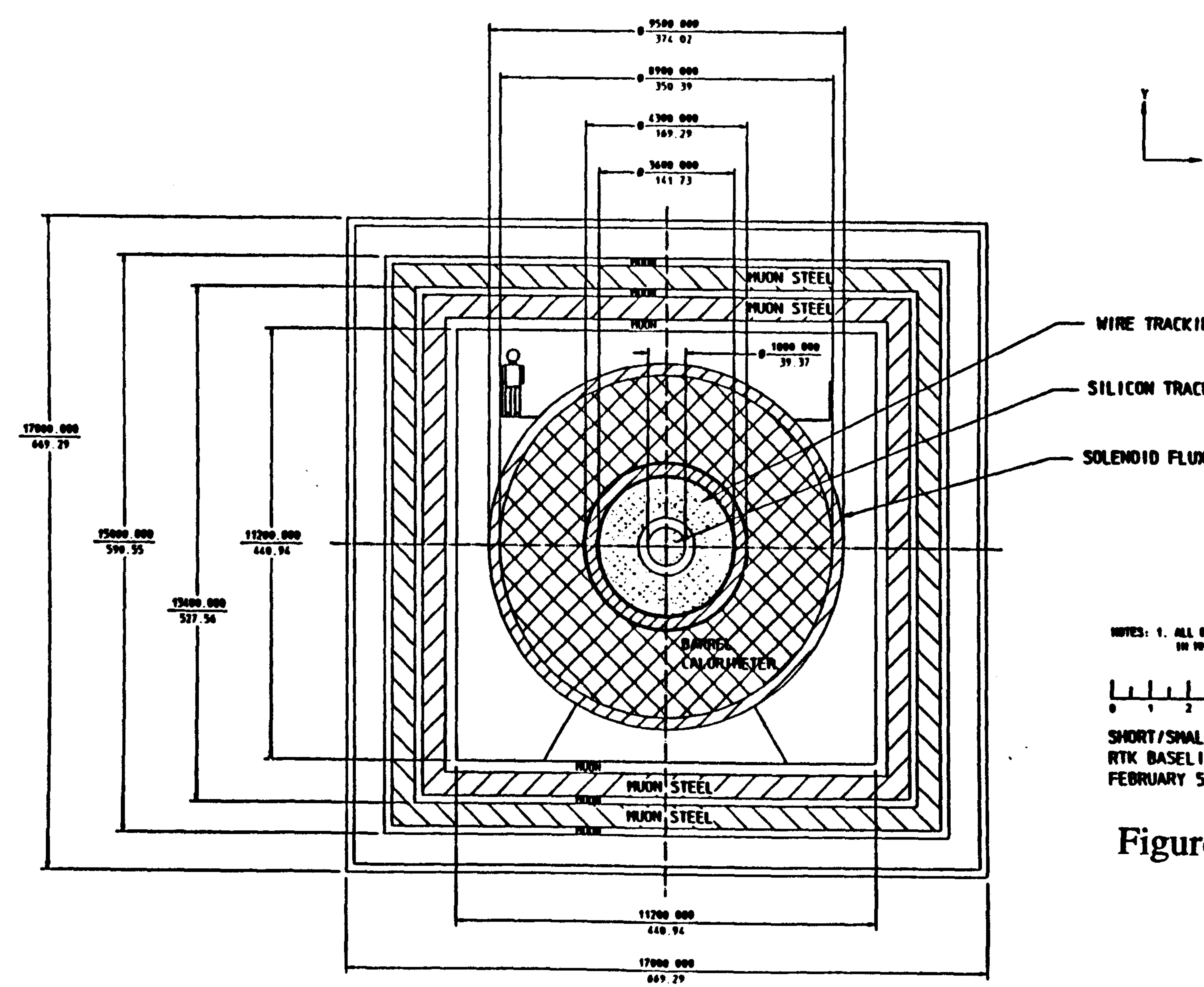
Table I: Experimental Halls Geotechnical Parameters
(West Cluster)

	IR1	IR2	IR3	IR4
Depth To Beam Line (ft)	178	171	137	143
Depth to Bottom of Excavation (ft)	219	210	197	174
Depth to Material Interface(ft)	218	211	168	180
Depth to limiting Load Countours (ft)	260	259	266	207
Excavated Volume (MCY)	0.25	0.57	0.48	0.55
Excavated Materials (per cent)	AC 100	AC 99 EFS < 1	AC 99 EFS 1	AC 100
Hall Volume (MCY)	0.04	0.10	0.24	0.03
Detector Axial Slope (deg)	0.09	0.09	0.09	0.09

Draft 02/08/90
Cut and Cover Construction
MYC = Million Cubic Yards

Table II: Power Consumption

Source	400 Hz	60 Hz Expt	60 Hz (other)	DC	Line Power
INSIDE COIL					
Silicon Tracking	20.0	0.5			
Straw Tracking	12.4	0.3			
Total Inside Coil	32.4	0.8			
INSIDE μ TOROID					
Calorimeter	160.0				
μ Chamber	1.4				
μ Trigger Scint.	12.0				
Trk LV Power Supplies	32.4				
Total Inside Toroid	205.8				
OUTSIDE μ TOROID					
μ Toroid Coils				2500.0	
μ Chamber	8.1				
μ Triggger Scint.	84.0				
Forward Calorimeter	11.2				
Level 1 Trig	240.0				
HV + Utilities		103.2	595.0		
Total Outside Toroid	343.3	103.2	595.0	2500.0	
UTILITY SHAFTS					
Power Bus				240.0	
Total Shafts				240.0	
SURFACE					
Data Acquisition	1200.0				
Level 2 Trigger	400.0				
Level 3 Trigger		400.0			
Control Room		400.0			
Cryogenics			190.0		2535.0
HVAC			1443.0		
Misc power		500.0	207.5		
μ Toroid pwr supplies					4212.0
400 Hz M/G Set					2212.0
60 Hz Detector					1423.0
60 Hz Other					4265.0
Total Surface	1600.0	1300.0	1890.5		14647.0
GRAND TOTAL	2181.5	1404.0	2485.5	2740.0	14647.0



NOTES: 1. ALL DIMENSIONS ARE IN MM OVER INCHES.

0 1 2 3 4 5 METERS

SHORT/SMALL SOLENOID
RTK BASELINE - SECTION
FEBRUARY 5, 1990

Figure 1.

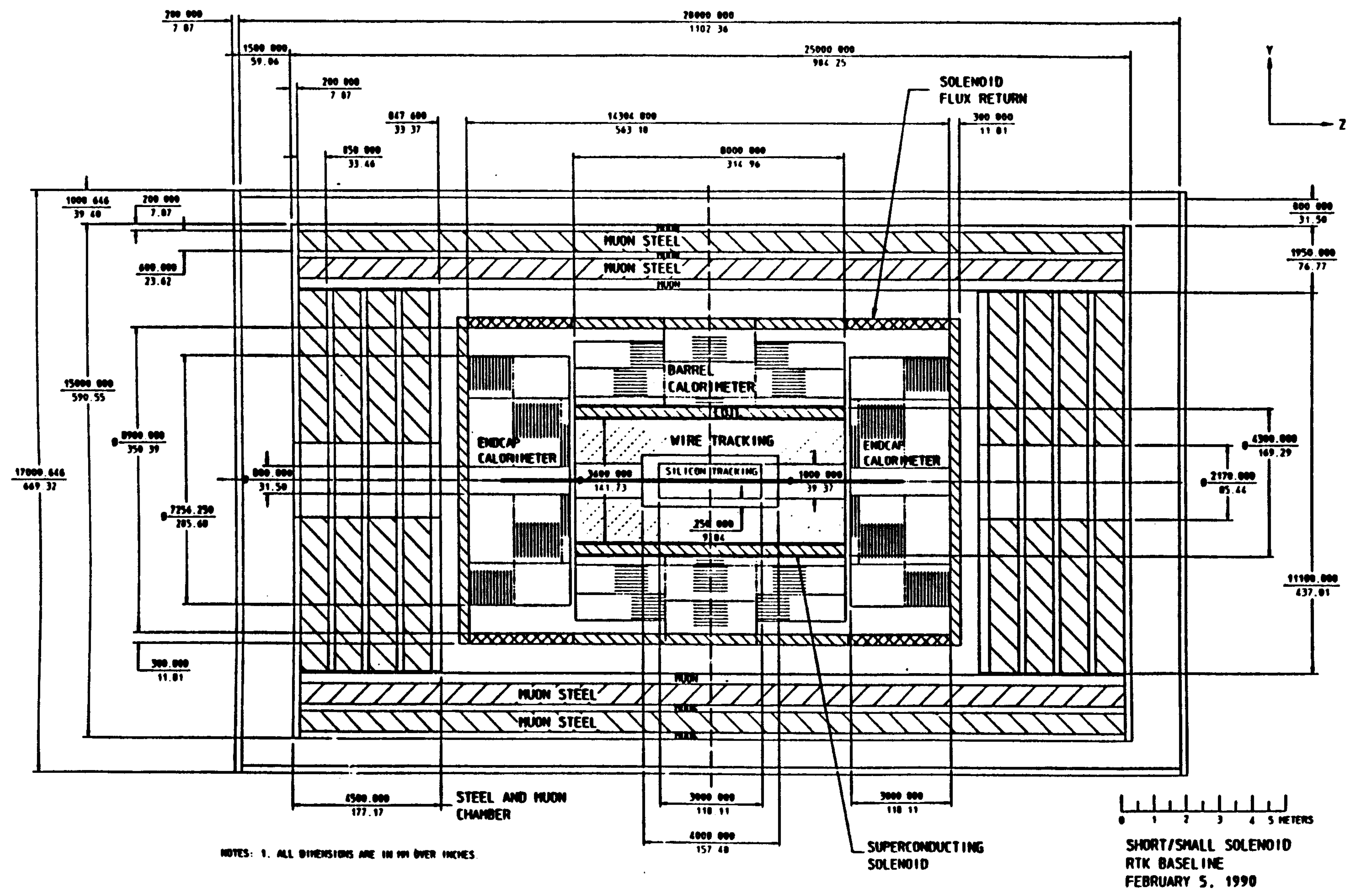

SOLENOID
FLUX RETURN
MUON STEEL
MUON STEEL
BARREL
CALORIMETER
COIL
WIRE TRACKING
SILICON TRACKING
ENDCAP
CALORIMETER
ENDCAP
CALORIMETER
MUON STEEL
MUON STEEL
STEEL AND MUON
CHAMBER
SUPERCONDUCTING
SOLENOID
NOTES: 1. ALL DIMENSIONS ARE IN MM OVER INCHES.
0 1 2 3 4 5 METERS
SHORT/SMALL SOLENOID
RTK BASELINE
FEBRUARY 5, 1990

Figure 2.

Figure 3.

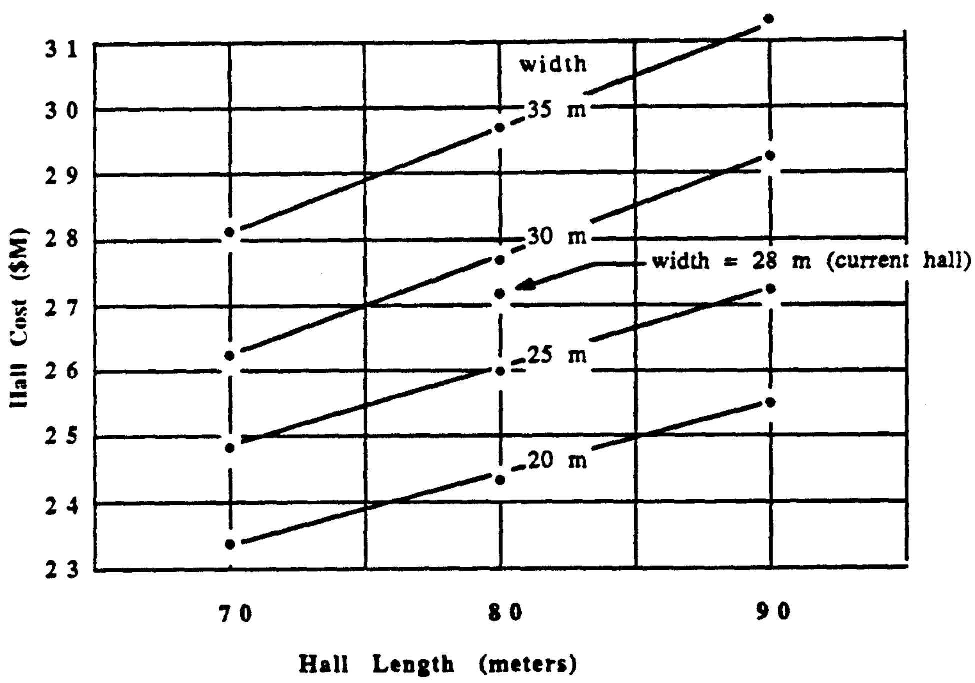
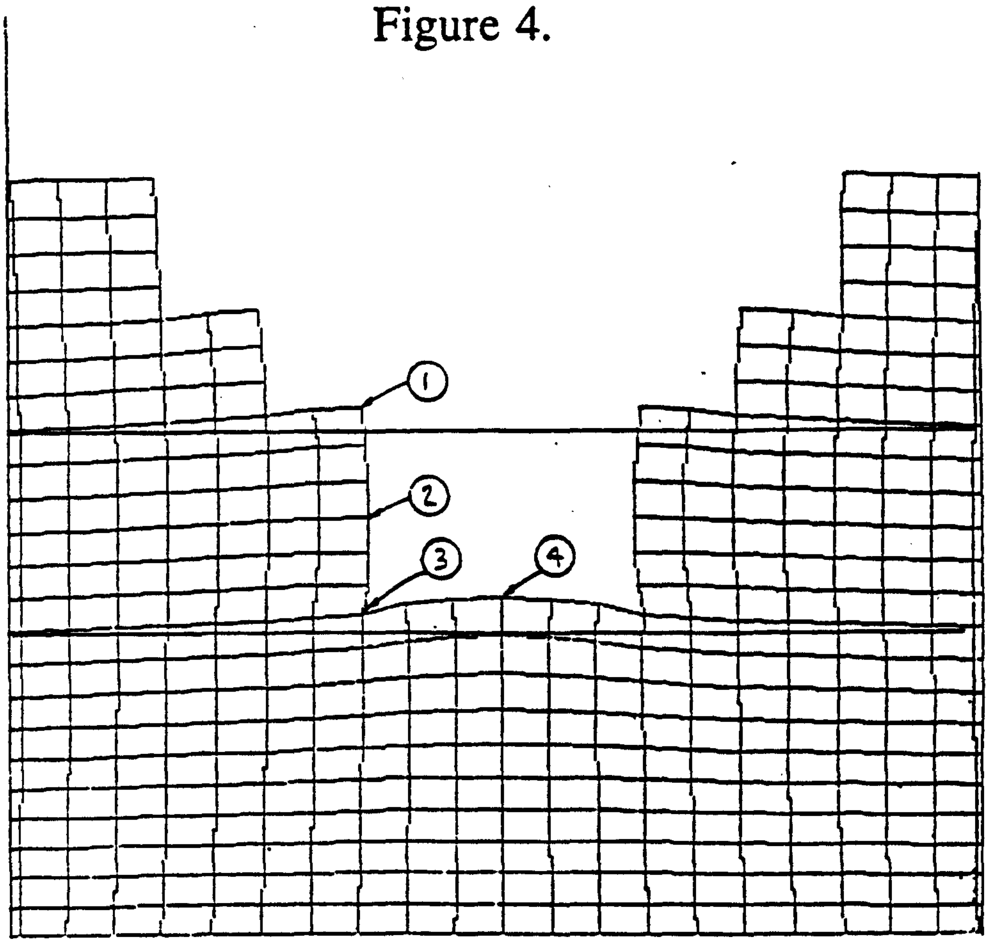

width
35 m
30 m
width = 28 m (current hall)
25 m
20 m
3 1
3 0
2 9
2 8
2 7
2 6
2 5
2 4
2 3
Hall Cost ($M)
7 0
8 0
9 0
Hall Length (meters)

Figure 4.



Estimated Rock Movements (inches)

Rock Properties		Movement	Location				Net Heave
E(ksi)	Poisson		1	2	3	4	(4-3)
17.5	0.35		5.7	4.3	8.8	14.2	5.4
35.0	0.35	Vertical	2.8	2.2	4.4	7.1	2.7
35.0*	0.40		5.5	4.1	4.3	7.0	2.7
17.5	0.35		1.7	3.5	1.2	0.0	
35.0	0.35	Horizontal	0.8	1.7	0.6	0.0	
35.0	0.40		1.1	2.0	0.8	0.0	

*Lab Values

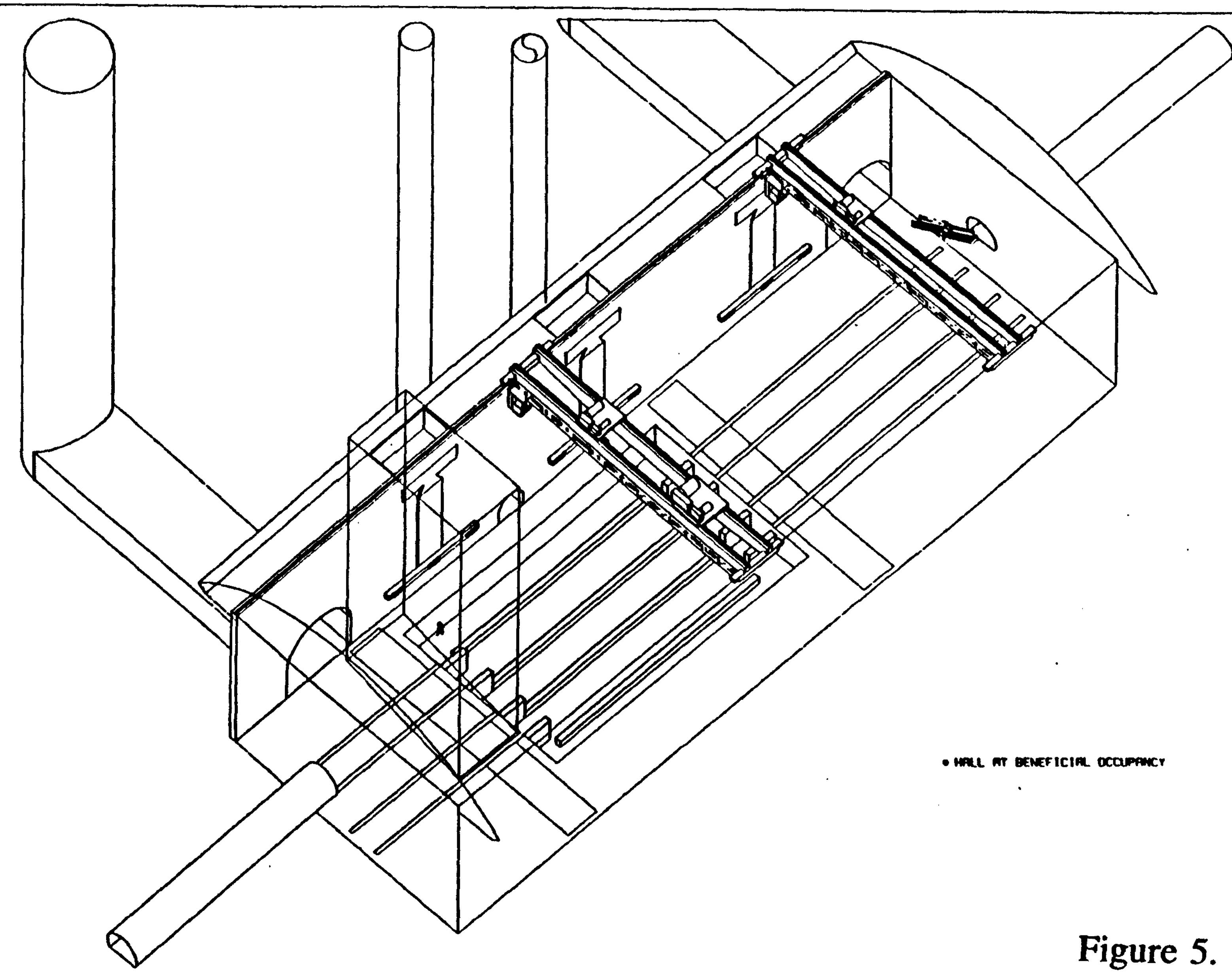
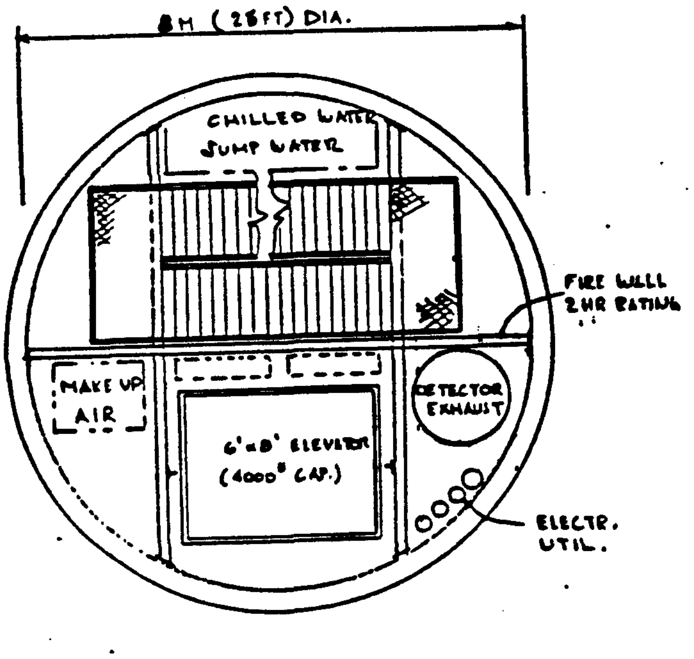


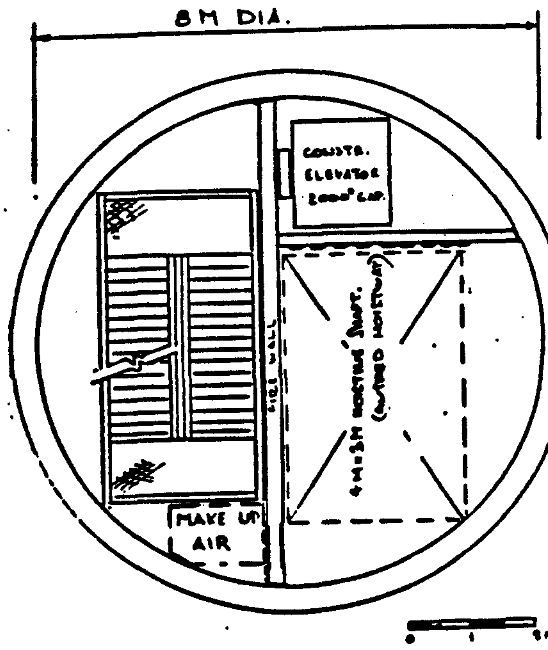
Figure 5.

RTK BASELINE DETECTOR CONSTRUCTION SEQUENCE
HALL AT 0 MONTHS

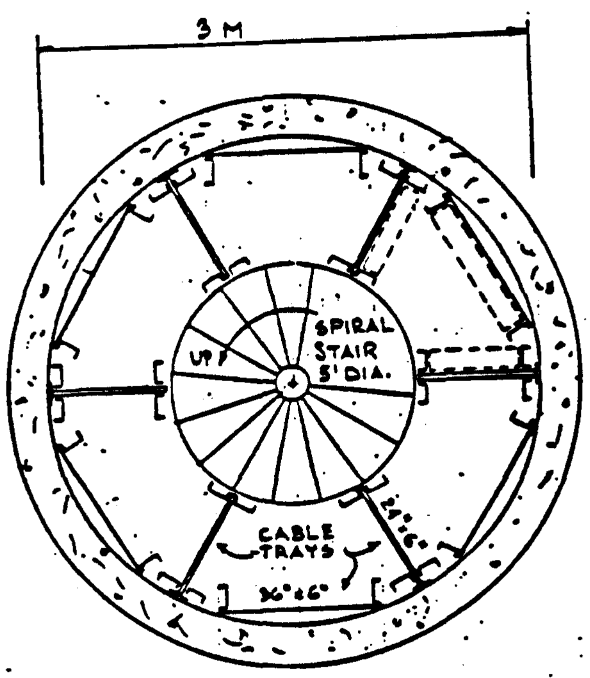
Figure 6.



(a) PERSONNEL SHAFT

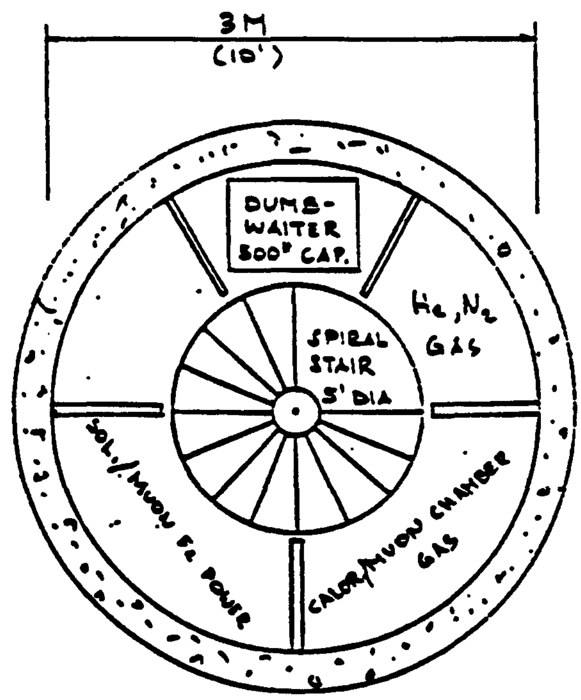


(b) EQUIPMENT SHAFT



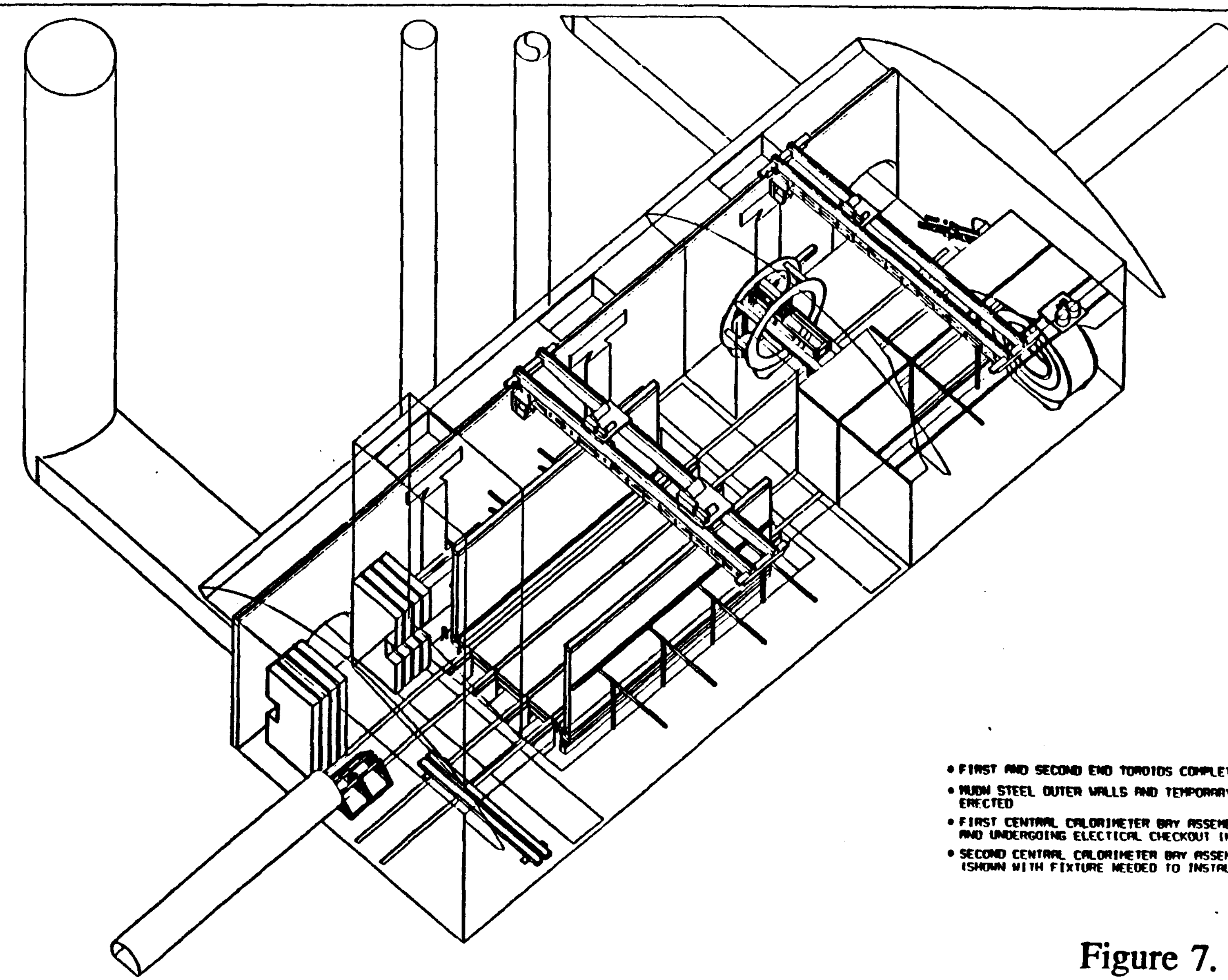
(c) CABLE SHAFT PLAN

TOTAL AREA IN TRAYS = 1.95 M²



(d) UTILITY SHAFT

TOTAL NET UTILITY AREA = 35 FT²



- FIRST AND SECOND END TOROIDS COMPLETE
- MUON STEEL OUTER WALLS AND TEMPORARY SUPPORTS ERECTED
- FIRST CENTRAL CALORIMETER BAY ASSEMBLY COMPLETE AND UNDERGOING ELECTICAL CHECKOUT IN CLEAN ROOM
- SECOND CENTRAL CALORIMETER BAY ASSEMBLY IN PROGRESS (SHOWN WITH FIXTURE NEEDED TO INSTALL MODULES)

Figure 7.

RTK BASELINE DETECTOR CONSTRUCTION SEQUENCE
HALL AT 9 MONTHS

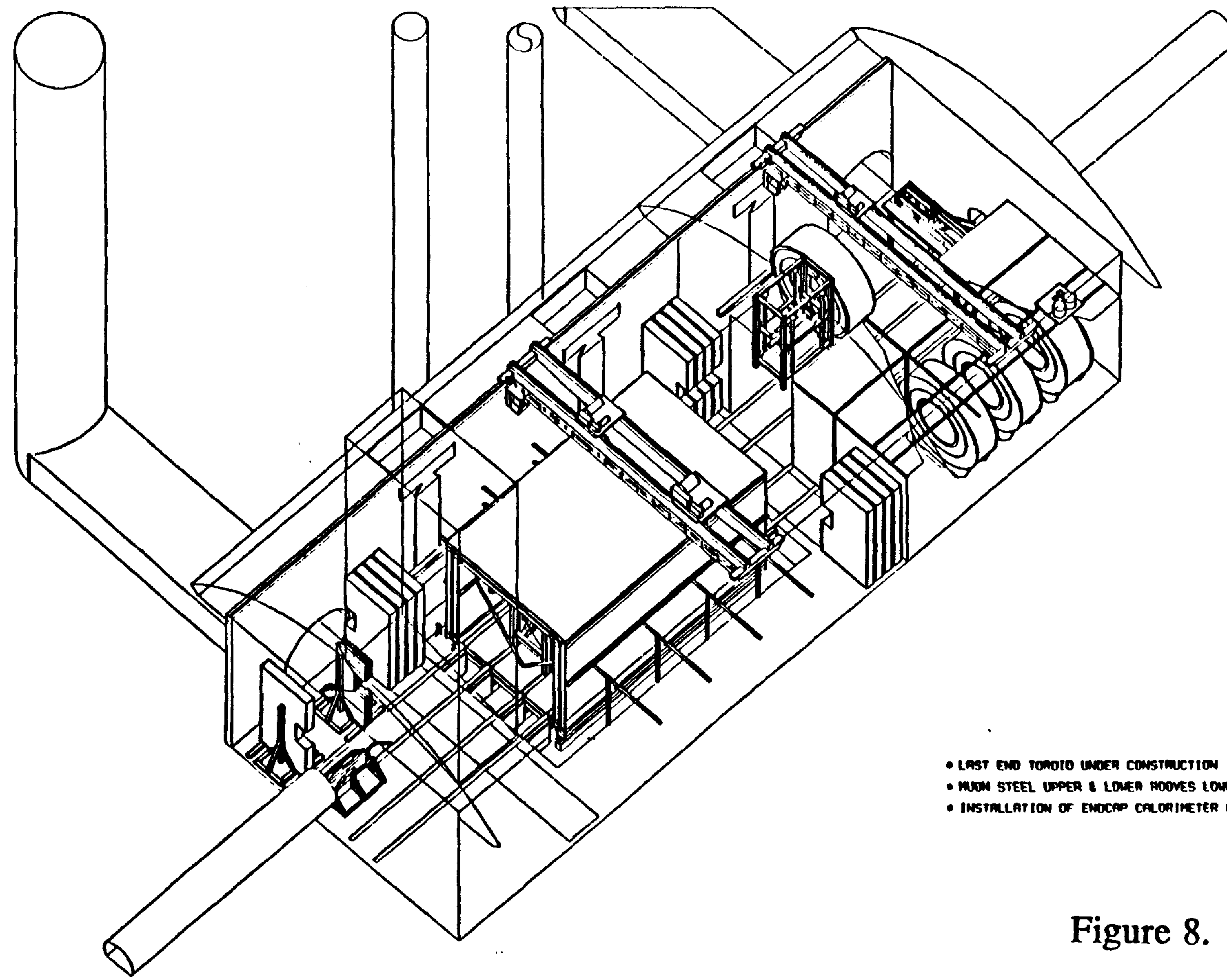


Figure 8.

ATK BASELINE DETECTOR CONSTRUCTION SEQUENCE
HALL AT 18 MONTHS

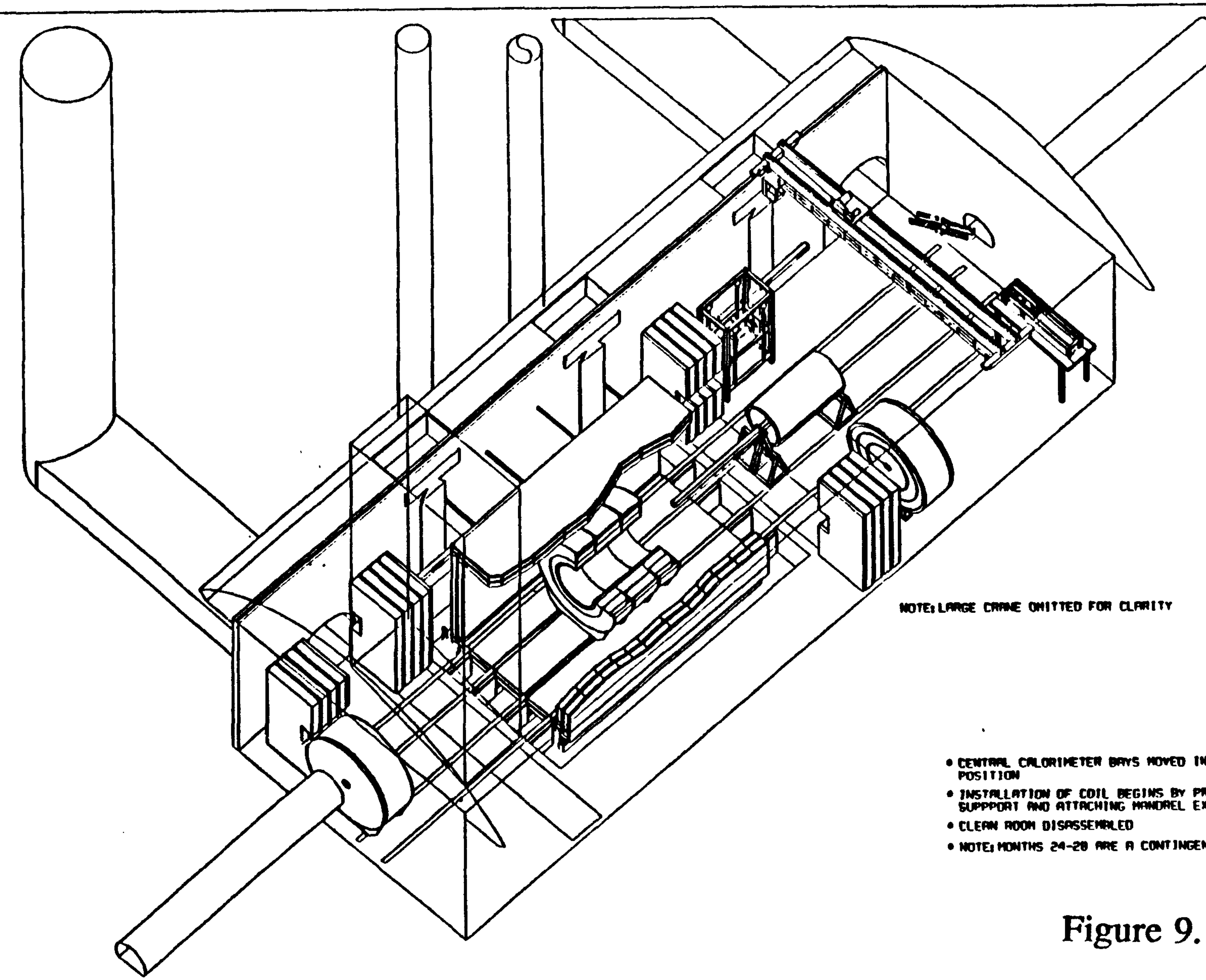


Figure 9.

RTK BASELINE DETECTOR CONSTRUCTION SEQUENCE
HALL AT 30 MONTHS

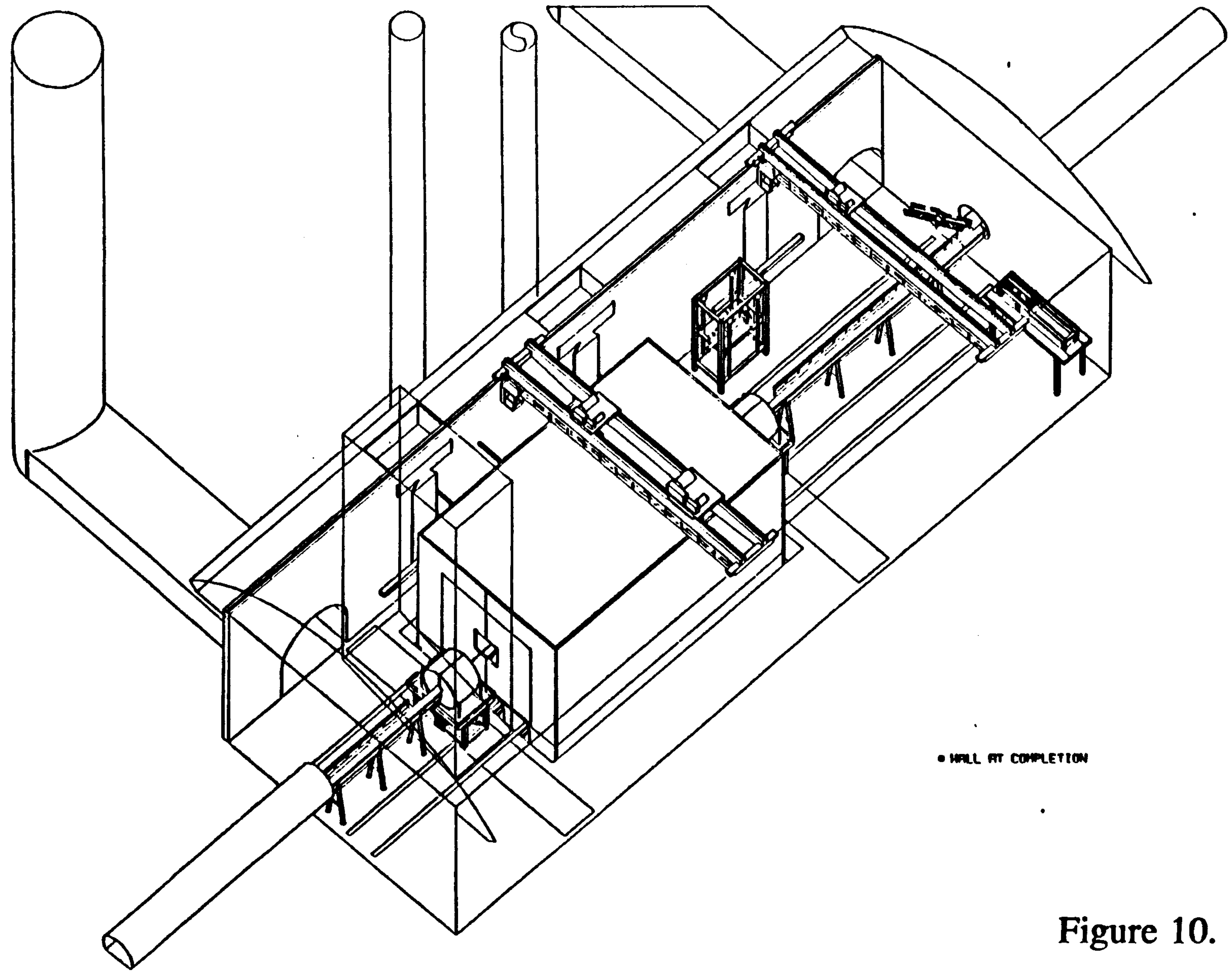


Figure 10.

RTK BASELINE DETECTOR CONSTRUCTION SEQUENCE
HALL AT 42 MONTHS

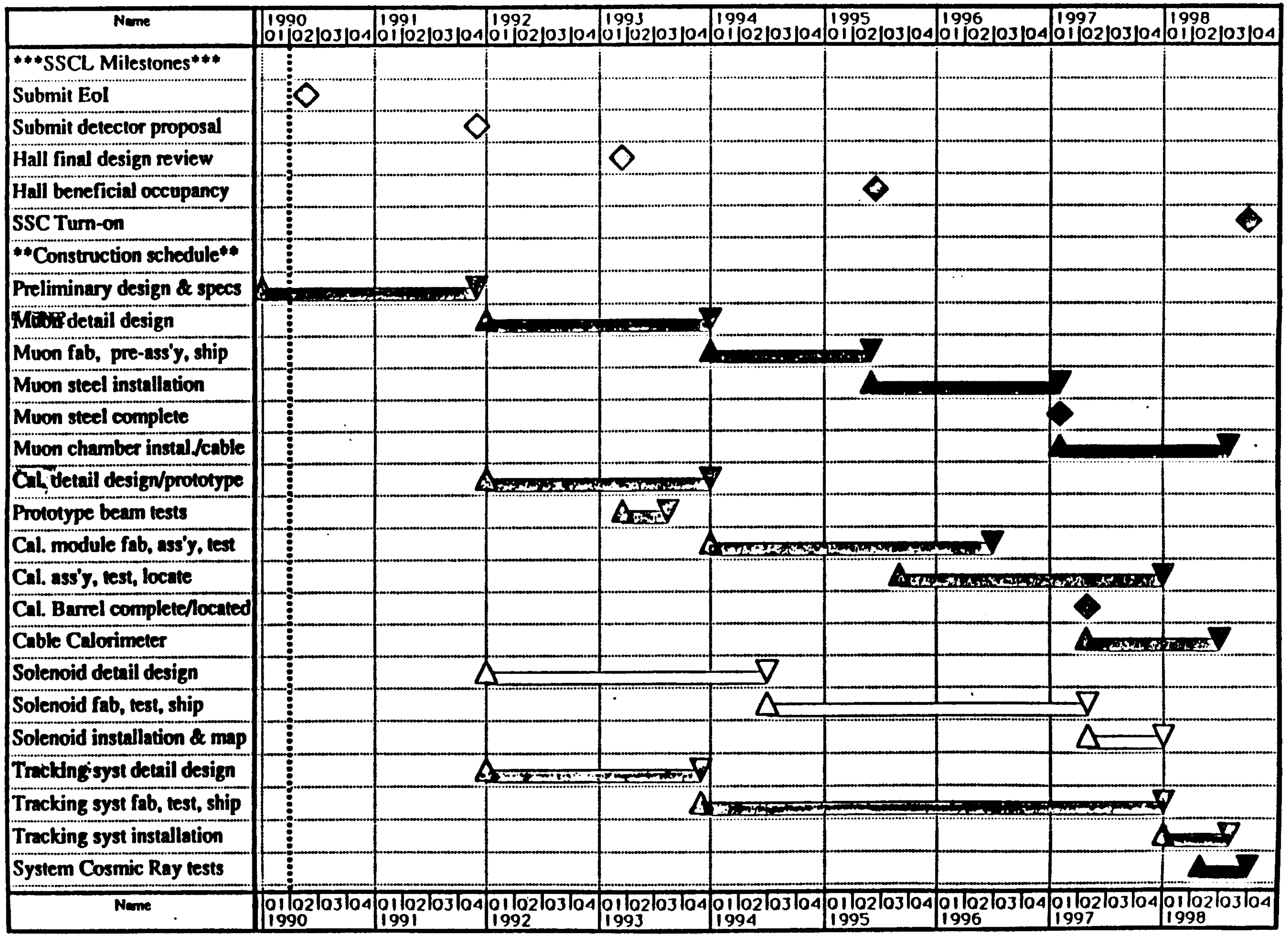

Name
1990
1991
1992
1993
1994
1995
1996
1997
1998
Q1
Q2
Q3
Q4
SSCL Milestones
Submit EoI
Submit detector proposal
Hall final design review
Hall beneficial occupancy
SSC Turn-on
Construction schedule
Preliminary design & specs
Muon detail design
Muon fab, pre-ass'y, ship
Muon steel installation
Muon steel complete
Muon chamber instal./cable
Cal. detail design/prototype
Prototype beam tests
Cal. module fab, ass'y, test
Cal. ass'y, test, locate
Cal. Barrel complete/located
Cable Calorimeter
Solenoid detail design
Solenoid fab, test, ship
Solenoid installation & map
Tracking syst detail design
Tracking syst fab, test, ship
Tracking syst installation
System Cosmic Ray tests

Figure 1